Tevatron Run-II Luminosities, Emittances and Collision point sizes

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Abstract: We compare the Tevatron luminosities as measured by the CDF and D0 experiments with those computed from machine characteristics. We also compare the CDF and D0 measurements of the size of the interaction regions with those predicted by machine parameters. Although the results are still preliminary, they show promise as a useful crosscheck of the instrumentation and our understanding of the Tevatron performance.

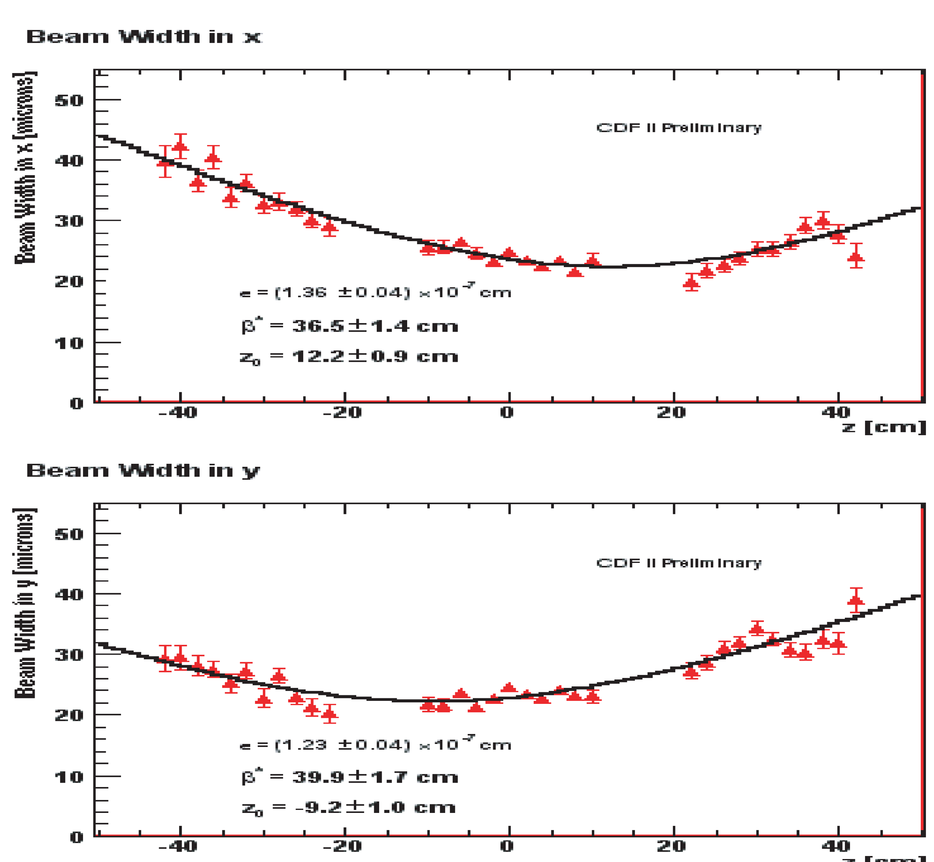
A collaboration between CDF, D0 and Beam Division to determine the basic factors that determines the Luminosity.

$$\mathcal{L} = \frac{10^{-6}\, f\, B\, N_p\, N_{\bar{p}} (6\beta_l \gamma_l)}{2\,\pi\,\beta^* \sqrt{(\epsilon_p + \epsilon_{\bar{p}})_x\,(\epsilon_p + \epsilon_{\bar{p}})_y}}\, H(\sigma_z/\beta^*)$$

$N_{p(\bar{p})}$ = number of protons (anti- protons) (e9)
B = number of bunches = 36
f = Revolution frequency = 47.7 kHz
$\beta_l\,\gamma_l$ = Lorentz boost = 1045. (E = 980)
β^* = Lattice β function at I.P ~ 35 cm
ε_p , $\varepsilon_{\bar{p}}$ = 95%, normalized transverse emitance (π mm mrad)
H = hourglass factor ~ 0.5 to 0.6

Three independent measurements of the transverse emittances are available : The CDF SVX detector, the Tevatron Flying Wires and the Synchrotron Light Monitor. We compare their performance.

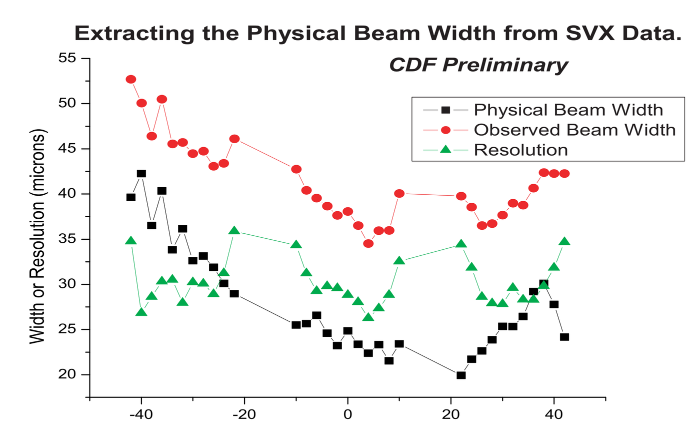
CDF SVX Analysis



Example plot showing the luminous region transverse size σ_x and σ_y versus Z and the fits to the equation:

$$\sigma = \sqrt{\epsilon_o \,(\beta^* + \frac{(z - z_0)^2}{\beta^*})}$$

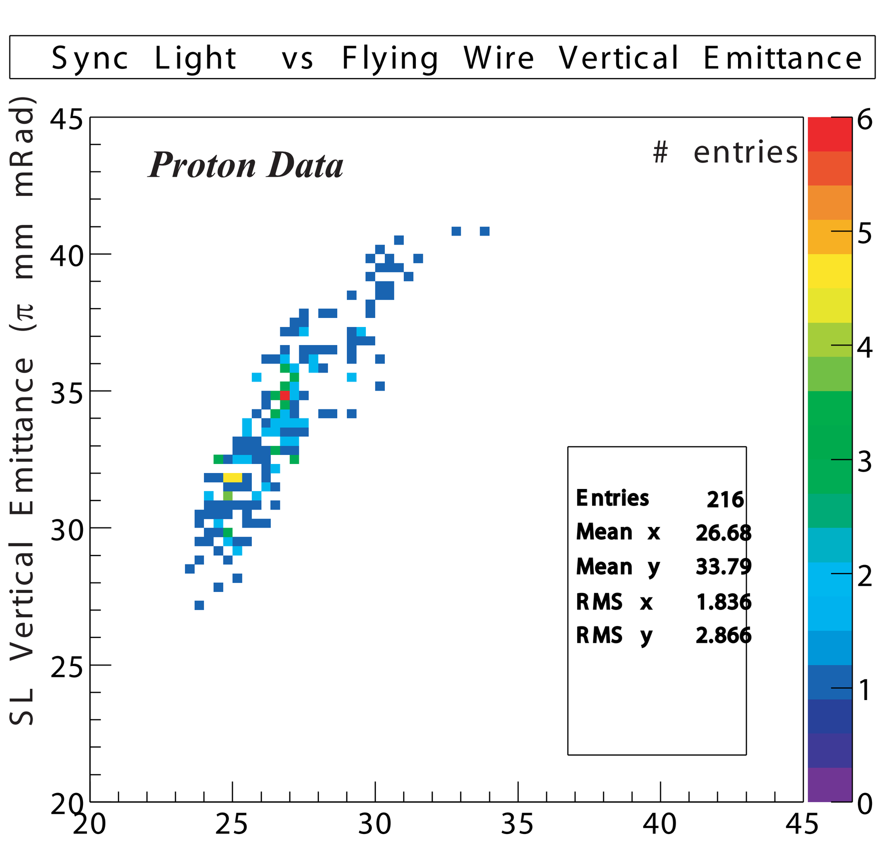
Typical correlation coefficient of the fits shown as a continuous black line are about -~ 0.8 for (β^*, e) and (β^*, z_0)



The vertex resolution must be subtracted out of the measured beam width. This plot gives the relative size of this important correction. Note that the vertex resolution does not strongly depend on the longitudinal position of these vertices. Therefore, we have almost independent information on the β^* and the equivalent beam emittance.

	β_x (cm)	β_y (cm)	$\varepsilon_{x\ \text{overlap}}$ π-mm-mr	$\varepsilon_{y\ \text{overlap}}$ π-mm-mr	Z_{0x} (cm)	Z_{0y} (cm)	equivalent emittance π-mm-mr
β_x, β_y free	38.6±2.5	38.0±3.0	7.9±1.1	7.8±1.0	14.2±1.6	-9.2±1.7	15.7±1.5
β_x, β_y fixed	38.6	38.0	8.0±1.1	7.9±1.1	14.3±3.1	-9.2±1.4	15.8±1.5
β_x, β_y fixed	35.0	35.0	8.3±1.2	8.1±1.2	13.3±1.1	-8.5±1.4	

Flying Wires and Synchroton Light Monitor Comparison



Example plot of some systematic studies on the correlation between the emittances reported by the Synchroton Light Monitor and those reported by the Flying Wires, measured at 980 GeV.
Similar plots and fits have been performed for both x and y planes, for both beams. The dispersion term has been taken into account. The momentum spread δp/p is measured by the Sample Bunch Display. The lattice function used in the calculation are known with ~ 10 %. Results are summarized on the table on the right.

$$\varepsilon_{SL} = \varepsilon_{FW} * \text{slope} + \text{Cst}$$

Plane/Beam	Slope	Cst
x, proton	1.12 ± 0.14	8.9 ± 2.0
y, proton	1.28 ± 0.17	-0.5 ± 4.7
x, anti-proton	0.65 ± 0.21	34.2 ± 4.3
y, anti-proton	0.64 ± 0.21	14.1 ± 6.5

for 5 recent stores, taken in early May 2003.

PAC 2003, TPPB070, May 13, 2003